

ESTIMATING FOOD INTAKE FROM SCATS IN THE OMNIVOROUS INDIAN FOX *VULPES BENGALENSIS*

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The Indian Fox *Vulpes bengalensis* is an omnivorous canid and has been reported to feed on a wide range of food items. However, the correction factor for assessing food intake from prey occurrence in scats has not been evaluated. We determined the relationship between food intake and the number of field-collectible scats produced in three captive foxes. A total of 14 feeding trials were conducted with food items ranging from <2 gm (insects) to ~2,000 gm (rabbits and some body parts of goats). Foxes ate on an average of 178.24 ± 29.55 gm of food and produced 10.23 ± 1.39 collectible scats/individual/day during feeding trial experiments. The percentage of non-collectible scats ranged from 2.98% to 12.22%, and averaged 7.14% (0.77 SE) of total scats produced. Digestibility index was lowest for smaller prey items. The prey biomass eaten per collectible scat (Y) increased as the live body weight of prey (X) increased ($Y = 0.013$ (SE 0.002) $\times$ prey weight (gm) + 6.76 (SE 2.25), $R^2 = 0.78$, $F_{(1,11)} = 39.43$, $P = 0.0001$), which can be used to compute biomass consumption from scat data.

Key words: biomass consumption, digestibility, feeding trials, linear regression

INTRODUCTION

Accurate knowledge of food consumed by carnivores is essential to understand their ecology and help formulate conservation strategies. Studies on the feeding ecology of carnivores are widely carried out by scat analysis. Scat analysis is non-invasive, cost-effective, and determines the range of food items utilised by carnivores (Corbett 1989; Reynolds and Aebischer 1991). Various methods have been widely used to interpret scat data across carnivore taxa. The most commonly used method for scat data interpretation is frequency of occurrence, which is expressed as the proportion of scats containing a particular prey item (Klare *et al.* 2011; Reynolds and Aebischer 1991). This estimate is biased towards prey with a smaller body size because smaller animals have a higher surface to volume ratio than larger animals (Floyd *et al.* 1978; Mech 1970) and therefore have more indigestible material per unit mass. Therefore, a correction factor developed from feeding trial experiments needs to be applied to estimate the actual biomass consumed from frequency of occurrence in scats (Ackerman *et al.* 1984; Floyd *et al.* 1978; Jethva and Jhala 2004; Lockie 1959; Mukherjee and Goyal 2004; Ruhe *et al.* 2008; Wachter *et al.* 2012). Such a relationship is lacking for the Indian Fox. The conversion factor for calculating biomass consumption has been developed for Red Fox *Vulpes vulpes* (Lockie 1959; Ruhe *et al.* 2008). However, this conversion may not be applicable for the Indian Fox *Vulpes bengalensis* due to its smaller body

size (<3 kg) and diet which mainly consists of smaller food items such as arthropods, rodents, reptiles, and fruits (Home and Jhala 2009; Manakadan and Rahmani 2001; Maurya 2012; Vanak and Gompper 2009) in semi-arid habitats of the Indian subcontinent. Hence, we carried out an investigation to find out the relationship between prey mass eaten and the number of scats produced through feeding trials on captive Indian Fox.

MATERIAL AND METHODS

Feeding trial experiments were carried out at the field base camp of Wildlife Institute of India in Abdasa taluka (23° 17' N; 68° 56' E), the south-western province of Kachchh district of north-western Gujarat, India. Three captive subadult foxes (a male and two females) were used for feeding trials following the procedure suggested by Floyd *et al.* (1978) and Jethva and Jhala (2004). Before commencing each trial, foxes were fasted for 48–72 hours, to clear their digestive system and reduce the effect of the previous diet. A total of 14 feeding trials of seven different food items were conducted (Table 1). A single food type was given in each trial. Water was provided *ad libitum*. Rabbit *Oryctolagus* spp., rat *Rattus norvegicus*, Indian Desert Jird *Meriones hurrianae*, chicken *Gallus domesticus*, reptiles, insects, and fruits were provided whole, whereas only parts of goat *Capra hircus* were provided (1–2 kg). Food items were kept in the enclosure until the foxes stopped feeding on them. No further food was provided

until scat production ceased (110 hrs average time). Most of the edible portion of the prey items was consumed within 2 days for large prey, such as rabbit and goat parts. However, rodent, insects, reptiles, and fruits were consumed on the same day of the feeding trial. Uneaten prey items were removed and weighed (0.1 gm accuracy) to determine the amount of food consumed.

Since weight of uneaten parts needs to be subtracted from food offered to compute the consumed amount, it was necessary to compute moisture loss from the food parts that were not consumed. Moisture loss from provided food items was assessed for 12–84 hrs. Known weight of food items were exposed to the environment and weighed every 12 hrs. Moisture loss rate per hour was calculated for each food item by computing percent of weight loss due to evaporation. Thus, the consumed food weight was calculated by accounting for the amount of moisture lost from the non-consumed part of food weight.

Scats were classified into two categories according to their structure: collectible (firm faeces) and non-collectible (watery and loose faeces) (Floyd *et al.* 1978; Jethva and Jhala 2004). Scats were collected three times in a day in order to minimise trampling. All the scats produced during the feeding trials were collected and sun dried for 4–5 days (noon temperature >40° C and 5–10% humidity), and weighed to nearest 0.1 gm. For each food item, we divided the amount (gm) of food eaten by the number of collectible scats to estimate the amount eaten that produced a (collectible) scat.

Simple linear regression analysis (Ackerman *et al.* 1984; Floyd *et al.* 1978; Jethva and Jhala 2004) was used to establish a relationship between biomass consumed per collectible scat (y) and food item weight (x). Outliers were excluded from the final regression using criteria more than two standard errors in residual diagnostic process (Zar 1984). Recently, Wachter *et al.* (2012) developed a polynomial regression model for Cheetah *Acinonyx jubatus*, but we did not adopt this approach as the offered food items were within the range a fox would consume in the wild, and therefore, the biomass consumed per collectible scat would not reach an asymptote for the range of prey items fed to the foxes. Digestibility index (D) was calculated using fresh weight consumed and fresh weight of scats (Robbins 1983; Ruhe *et al.* 2008).

$$\text{Digestibility Index} = \frac{\text{Fresh weight of prey consumed} - \text{Fresh weight of all collectible scats}}{\text{Fresh weight of prey consumed}}$$

RESULTS

Foxes completely consumed smaller food items like rodents, beetles, and reptiles on the same day, while larger food items weighing (>2 kg) like rabbit, chicken, goat's leg and fruits were fed upon for 2 days. Average consumption by foxes was $87_{\text{Mean}} \pm 3.7_{\text{SE}}\%$ (min=55%, max=100%) of the

Table 1: Details of feeding trials on three Indian Fox

S. No.	Food Items	Food Weight (gm)		Food used (%)	Scats		Digestibility Index (%)	Amount (gm) eaten per collectible scat
		Offered	Consumed		Collectible	Non-Collectible		
1	Beetles	85	85.0	100	20	0	32.94	4.25
2	Beetles	225	225.0	100	36	7	53.56	6.25
3	Rabbit	1630	1511.0	93	53	29	89.58	28.51
4	Rabbit	1530	1407.6	92	51	27	91.90	27.60
5	Rodents	205	205.0	100	13	9	67.80	15.77
6	Rodents	1050	920.0	88	67	3	80.16	13.73
7	Chicken	1200	759.5	63	25	31	93.81	30.38
8	Chicken	1520	1200.2	79	45	7	88.67	26.67
9	Reptiles	341	341.0	100	30	2	83.87	11.37
10	Goat	1850	1023.7	55	34	7	91.01	30.11
11	Goat	1050	853.1	81	22	14	91.50	38.78
12	Ziziphus fruit	600	497.9	83	23	36	70.08	21.65
13	Phoenix fruit	500	465.3	93	36	3	74.96	12.93
14	Phoenix fruit	500	436.5	87	44	1	74.34	9.92

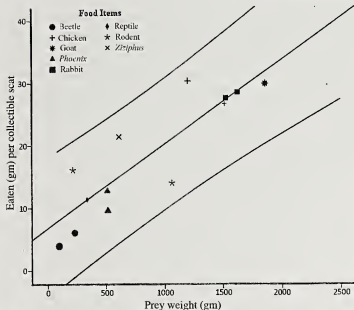


Fig. 1: Linear regression (with 95% confidence interval) between biomass consumed per collectible scat (Y) and average weight of food items (X) ($Y = 0.013$ (SE 0.002) $\times$ prey weight (gm) + 6.76 (SE 2.25), $R^2 = 0.78$, $F_{(1,11)} = 39.43$, $P = 0.0001$)

offered food weight (Table 1). Foxes consumed most of the soft body portion of larger food items. Only bones and hide were left unconsumed. The average percentage weight loss due to evaporation within 48 hours was highest for chicken (4.9%) and goat's leg (4.5%), than fruits (2.1%) and rabbit (1.1%). The percentage of non-collectible scats ranged from 2.98% to 12.22%, and averaged 7.14% (0.77 SE) of total scats produced.

Food consumption by foxes was correlated to the digestibility of food items. Digestibility of beetles was lowest, followed by chicken, rabbit, fruits, and rodents (Table 1). Digestibility index averaged 77.4% (SE=4.6) and was positively correlated to the weight of food item ($r_s = 0.82$, $p=0.0001$), while the percentage of food items consumed was negatively correlated to digestibility ($r_s = -0.65$, $p=0.006$). Foxes ate on average $178.24_{\text{Mean}} \pm 29.55_{\text{SE}}$ gm of food and produced $10.23_{\text{Mean}} \pm 1.39_{\text{SE}}$ collectible scats/individual/day during the feeding trial experiments. There was a strong relationship between prey weight and the number of scats produced during feeding trials. One feeding trial of goat was detected as an outlier (std. residual=2.48) among the 14 sample data sets and excluded from further analysis. The prey biomass eaten per collectible scat (Y) increased as the live body weight of offered prey (X) increased (Fig. 1). A regression on these variables generated the following equation: $Y = 0.013$ (SE 0.002) $\times$ prey weight (gm) + 6.76 (SE 2.25), $R^2 = 0.78$, $F_{(1,11)} = 39.43$, $P = 0.0001$, which can be used to assess the quantity of biomass consumption from different food items recorded in fox scats. Individual

correction factors for broad food items for biomass (gm) consumed per collectible scat were 5.3 (SE 1) for arthropods, 25.75 (SE 3.9) for mammals, 28.5 (SE 1.9) for birds, 11.4 for reptiles, and 14.8 (SE 3.5) for fruits.

DISCUSSION

The Indian Fox is a small canid (<3 kg body weight) and an opportunistic solitary forager that feeds on food items smaller than its body mass, mainly consisting of arthropods, rodents, hare, reptiles, birds, fruits, and occasionally scavenging on livestock carcasses (Home and Jhala 2009; Maurya 2012; Vanak and Gompper 2009). Most of the food items offered during our feeding trial experiments conducted were consumed on the same day as also observed in free ranging foxes through radio-telemetry (Maurya 2012). Rodents, arthropods, and reptiles were consumed whole including the fur, bones, and scales, while mostly soft and edible parts were eaten from livestock carcasses. Although, livestock carcasses such as goats, sheep and cattle are not important food items in their diet, constituting less than 1% (Home and Jhala 2009; Maurya 2012), we included them in the experiment to cover the range of species utilised by them. The Indian Fox diet of livestock are leftover parts of kills made by other large predators, such as wolves and hyenas, and thus, they try to consume the most digestible part quickly due to risk of encounters with the larger carnivores, while feeding on the carcasses.

The digestibility of larger food items was higher than smaller prey as reported from other studies (Floyd *et al.* 1978; Jethva and Jhala 2004; Ruhe *et al.* 2008) because smaller prey species have a greater proportion of indigestible materials than larger prey species, and therefore consumption of small prey species resulted in a higher number of collectible scats. The mean digestibility of arthropods and mammalian prey items in Indian Fox was similar to that reported for Red Fox *Vulpes vulpes* (Ruhe *et al.* 2008) and Badger *Meles meles* (Rosolino *et al.* 2003). Litvaitis and Mautz (1976) fed Snowshoe Hare *Lepus americanus* and White-tailed Deer *Odocoileus virginianus* to captive Red Fox and estimated digestible dry matter at 82% for hare and at 97% for deer. Similarly, Johnson and Hansen (1979) reported that for coyotes *Canis latrans*, the digestibility of mammals was 80% and that of birds 60%. Thus, the digestibility index values obtained in this study are comparable to these studies and also in agreement with the hypotheses that, in terms of weight, small prey were over represented in frequencies of remains in fox scats (Floyd *et al.* 1978; Jethva and Jhala 2004; Ruhe *et al.* 2008; Weaver 1993). We observed that when fruits especially of *Ziziphus* were fed to foxes, a large number of

non-collectible scats (Table 1) were produced. These non-collectible scats were usually grayish black and fluid, reflecting low digestibility, and would generally be missed during field studies (Ackerman *et al.* 1984; Floyd *et al.* 1978).

The average body weight of an adult Indian Fox is $2.24_{\text{Mean}} \pm 0.13_{\text{SE}}$ kg (Johnsingh and Jhala 2004; Maurya 2012). From our data, the daily food intake for foxes was computed to be 0.112 kg fresh weight per kg body mass or about 0.25 kg fox⁻¹ day⁻¹ and the daily food intake per metabolic body weight (McNab 1980) was 0.14 kg kg^{-0.75}. The consumption rate of food in Indian Fox was found to be lower than that recorded for the Red Fox (0.22 kg/MBW Stahl 1990; 0.24 kg/MBW Webbon *et al.* 2004). Sargeant (1978) reported food consumption of adult Red Fox 2.48 kg/adult/week (0.69 kg kg^{-0.75} prior to whelping, and 3.62 kg/adult/week (1.01 kg kg^{-0.75}) after whelping. In arid habitats foxes have smaller body mass and lower basal metabolic rate (BMR), e.g., Fennec Fox *Vulpes zerda* (281.1 kJ/d, Maloiy *et al.* 1982), Kit Fox *Vulpes macrotis* (485.5 kJ/d, Golightly and Ohmart 1983), Blanford's Fox *Vulpes cana* (304.5 kJ/d, Williams *et al.* 2004) and Rüppell's Fox *Vulpes rueppellii* (385.4 kJ/d, Williams *et al.* 2002) in comparison to foxes inhabiting mesic environments, e.g., Red Fox (1,195.5 kJ/d Williams *et al.* 2004). We find support for the hypothesis that lower consumption of food by the Indian Fox could be an adaptation to arid environment by lowering BMR so as to have a selective advantage in times of low resources abundance in arid environments (McNab 1980; Williams *et al.* 2004). In the wild, arthropods constitute a major portion of the Indian Fox diet (Home and Jhala 2009; Manakadan and Rahmani 2001; Maurya 2012; Vanak and Gompper 2009). Indian foxes are not known to hoard food; thus their survival and reproductive output seems to depend on regular foraging on energy rich food sources.

Ruhe *et al.* (2008) estimated the conversion factor for each prey species by dividing the prey mass offered by the dry mass of scat remains after washing through a 2 mm sieve. Lockie (1959) derived the correction factor by dividing the prey mass offered to Red Fox by the amount of undigested matter. Both these studies did not incorporate the actual amount of food consumed after correcting for moisture loss. In our study, we estimated the amount (gm) eaten per collectible scat and regressed this against prey weights offered, which provides estimate of biomass eaten per collectible scat from different size food items. We suggest that this regression relationship would be more robust for evaluating food habits

than individual conversion factors especially for mammalian, avian, and reptilian diet. However, the broad taxa based conversion factors developed by us for amount of biomass consumed to produce one collectible scat may be more appropriate for fruit and arthropod remains in scat (Atkinson *et al.* 2002; Loveridge and Macdonald 2003). The regression equation developed in this study, shows a significant relationship between weight of food offered and number of scats produced, as has been reported in wolf and cougar (Ackerman *et al.* 1984; Floyd *et al.* 1978; Jethva and Jhala 2004). Wachter *et al.* (2012) developed an exponential regression model to compute prey biomass consumed per collectible scat by cheetah, wherein after a certain large mass of prey, scat production reaches an asymptote. Since we offered food amounts that are likely to be naturally encountered in free ranging condition, we did not see an asymptote in the relation between prey weight and number of field collectible scats. Thus, our regression model is in the lower linear range of the exponential function. If however, foxes were offered full prey carcasses of goat, sheep, and cattle of >10 kg, we would expect an exponential model to fit better since the number of scats produced cannot increase indefinitely and reach a plateau at higher prey body masses. In the field, Indian Fox scats contains more than one prey item. To apply this equation to estimate biomass consumption, one should use the number of whole scats equivalents for a particular food item by adding the proportion of each food item constituting the scats rather than the percentage of occurrence (Maurya 2012). The regression relationship developed herein is likely to provide a more robust understanding on the diet of Indian Fox and related canids that feed on a mixed diet of fruit, arthropods, rodents, reptiles, and lagomorphs.

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